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Neutron-Proton Elastic Scattering 8 to 30 GeV/c*

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ABSTRACT

The differential cross section for neutron-proton elastic scattering was measured in the diffraction region with incident neutron momenta between 8 and 30 GeV/c. The experiment was a spark chamber-counter experiment, conducted at the A.G.S., in which a well collimated, multi-energetic neutron beam struck a hydrogen target. The angle and momentum of the exiting proton were determined by a spark-chamber spectrometer. The angle of the scattered neutron was determined by its interaction vertex in a thick plate spark chamber array. The overdetermined event was then subjected to a fitting procedure. Preliminary results based on 15% of the 480,000 photographed events are presented and compared to currently available lower energy n-p data and comparable energy p-p data.

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We report here preliminary results of an experiment to study neutron-proton elastic scattering in the diffraction region for incident neutron momenta between 9.4 and 29.4 GeV/c. This experiment, performed at the Brookhaven A.G.S., is a continuation of work done previously at the Bevatron[1] and employed the same techniques.

The experimental arrangement is shown schematically in Fig. 1. The internal A.G.S. proton beam, at a momentum of 29.4 GeV/c, was spilled on a small beryllium target. A neutron beam was taken off at an angle of 1° with respect to the circulating proton beam. This beam was carefully collimated so that at the hydrogen target it had a diameter of 3.3 cm with a negligible halo surrounding it. The defining collimator was a 2.5 cm diameter aperture located 35 m from the internal A.G.S. target.

Charged particles were removed from the beam by means of several sweeping magnets. Lead filters placed ahead of the first two sweeping magnets effectively removed γ's from the beam. The contamination of K°'s and $\overline{n}$'s in the beam was negligible. The estimated flux in the beam was 10^6 neutrons per 10^{11} interacting protons with a nominal neutron momentum range from 8 to 29.4 GeV/c.

The neutron beam was incident on a 30 cm long hydrogen target (Fig. 1). The scattered neutron was detected by its interaction in an array of thick plate spark chambers. The array contained a total of about 1.4 collision lengths of steel. The chambers were interspersed with scintillation counters to provide a trigger corresponding to a neutron interaction in the array. The neutron angle was determined with an accuracy of ±2 mr by connecting the vertex of the neutron initiated shower in the chambers with the proton track extended into the hydrogen target.

The recoil proton was detected in a spectrometer consisting of a 30" x 36" magnet with a pair of thin-foil chambers on each side of it.

The neutron and proton spark chambers were viewed with separate cameras. The triggering requirement was a fast coincidence between counters P_1, P_2, P_3, and any two successive counters in the neutron array with no vetoing pulse from either of the anti-counters, A_1 and A_2 (Fig. 1).

The proton spectrometer was mounted on rails to facilitate changing its position. In the course of the experiment the proton spectrometer assumed four positions covering overlapping angular ranges while the neutron detector assumed two positions. Relative normalization between the various settings was accomplished by means of several monitor telescopes in the neutron beam.

There was no attempt to make an absolute normalization internal to the experiment. The data presented are normalized to the optical point, neglecting the contribution from the real part of the forward scattering amplitude, so that

$$\frac{d\sigma}{dt}\bigg|_{\theta=0} = \frac{1}{\pi}\left(\frac{\sigma_T}{4\hbar}\right)^2$$

The total cross section σ_T was taken to be constant at 38 mb between 8 and 30 GeV/c.[2]

The measured quantities for each event are the neutron angles, the proton angles, and the proton momentum. The momenta of the incident and scattered neutron are unknown. This allows a 2-C fit to an elastic scattering. Events that gave satisfactory fits were binned according to the incident neutron momentum. The present results are based on approximately 15% of the total of 480,000 event candidates. The effective solid angle for each setting, incident neutron momentum, and four-momentum transfer was determined from a Monte Carlo calculation.

Our results are given in Figures 2 through 6. The cross sections all appear to fall off smoothly in $|t|$ and follow a $e^{-b|t|}$ dependence (where t is the square of the four-momentum transfer). The values of b are given on the plots and were obtained by doing a maximum likelihood fit to the data. They range from about 7.5 to 9.0$(\mathrm{GeV/c})^{-2}$. At the present statistical accuracy there is some indication that b increases with increasing incident momentum. This would correspond to a shrinking diffraction peak. When all of the data have been analyzed the statistical errors will be considerably smaller, and the results will extend to $|t| \cong 2(\mathrm{GeV}/c)^2$.

In Fig. 7, our results at 11.4 and 23.4 GeV/c are compared with results from the Bevatron experiment[1] at 6.8 GeV/c. It is apparent that the cross sections fall off considerably faster with t at the higher incident neutron momenta.

In Fig. 8, our cross sections at 23.4 GeV/c are compared with those for pp scattering at 21.8 and 24.6 GeV/c.[3] The agreement is quite good. On the basis of results from this experiment and the previous Bevatron experiment we conclude that the slopes of the diffraction peak for np scattering agree remarkably well with those for pp scattering over the momentum range 3 to 30 GeV/c.

It is our pleasure to acknowledge the assistance of the A.G.S. staff, particularly J. Sanford and W. Merkle, for their assistance in setting up and running the experiment. We would also like to thank G. DeMeester, O. Haas, S. T. Powell III, R. Seefred, J. Smith, and S. Wilson for their help with the setup.

References

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J. Cox, M. L. Perl, M. N. Kreisler, M. J. Longo, and S. T. Powell III, to be published in Phys. Rev. Letters.

2. M. N. Kreisler, L. W. Jones, M. J. Longo, and J. R. O'Fallon, Phys. Rev. Letters 20, 468 (1968).

3. K. J. Foley, R. S. Gilmore, S. J. Lundenbaum, W. A. Love, S. Ozaki, E. H. Willen, R. Yamada, and L. C. L. Yuan, Phys. Rev. Letters 15, 45 (1965).

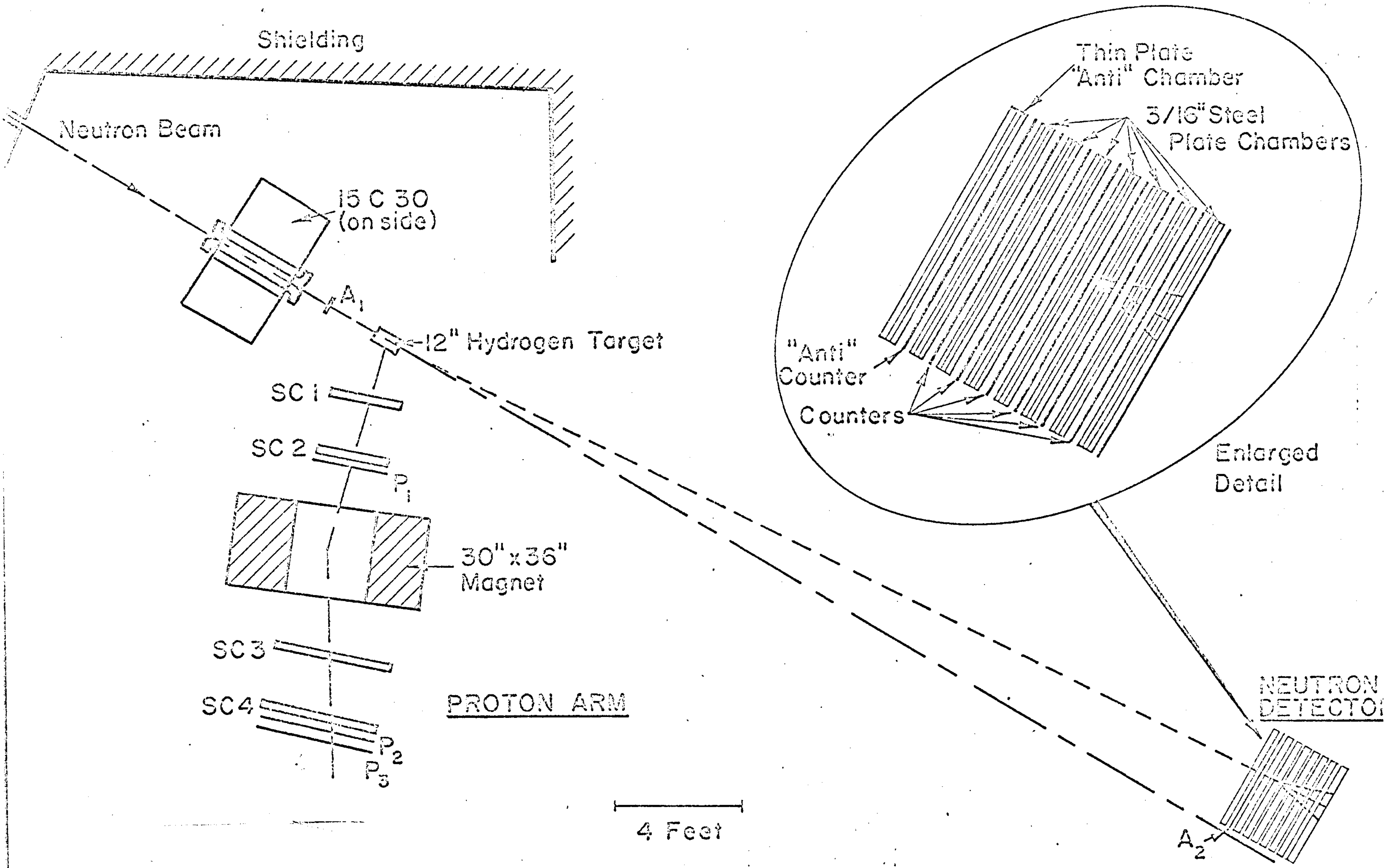
Figure Captions

Figure 1. Experimental arrangement.

Figures 2-6. Differential cross sections for 4 GeV/c intervals of the incident neutron momentum with lines representing maximum likelihood fits.

Figure 7. Comparison of np cross sections at incident momenta of 6.8[1], 11.4, and 23.4 GeV/c.

Figure 8. Comparison of np and pp[3] differential cross sections.



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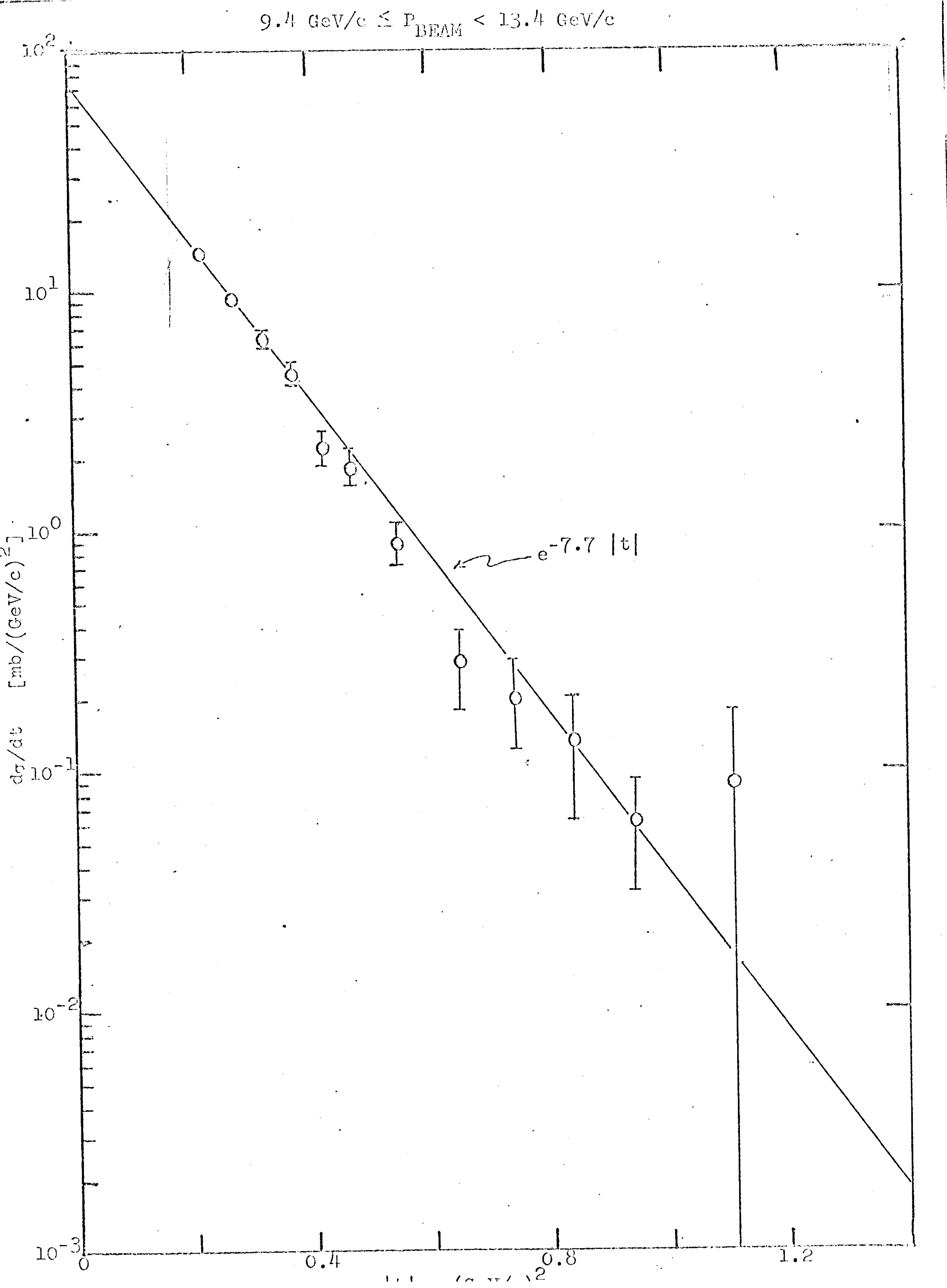
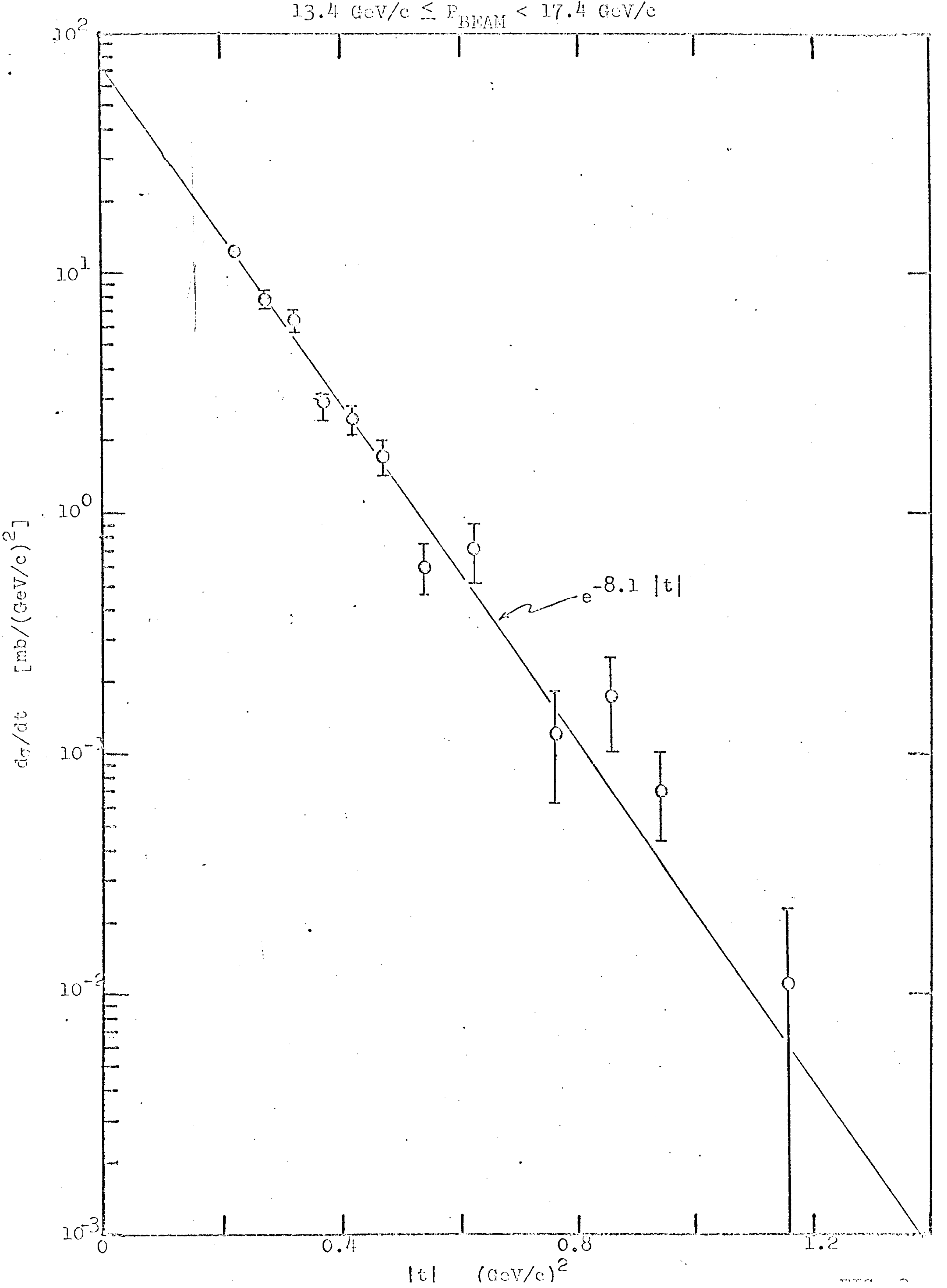
n - p ELASTIC SCATTERING EXPERIMENT

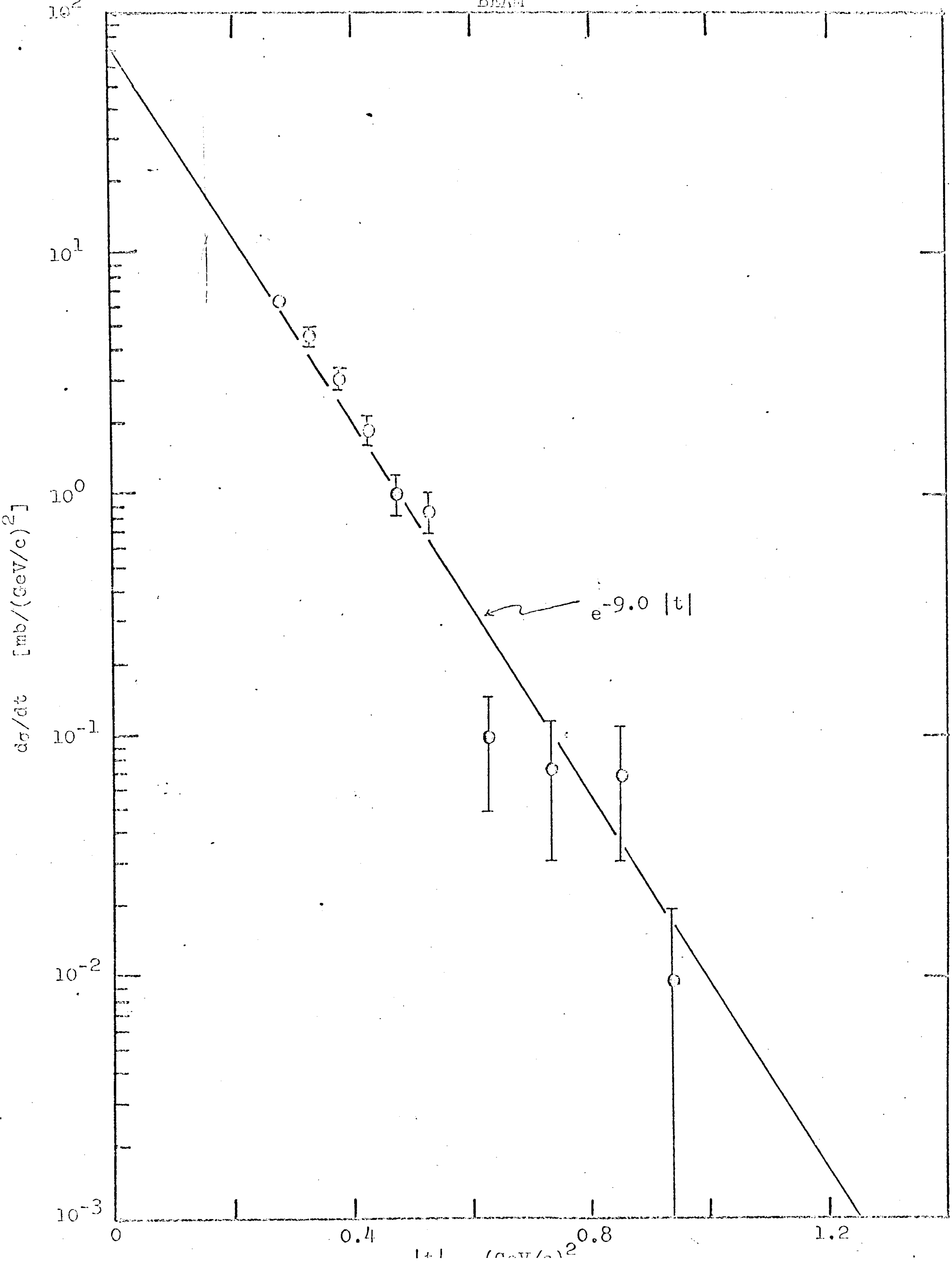
FIG. 1

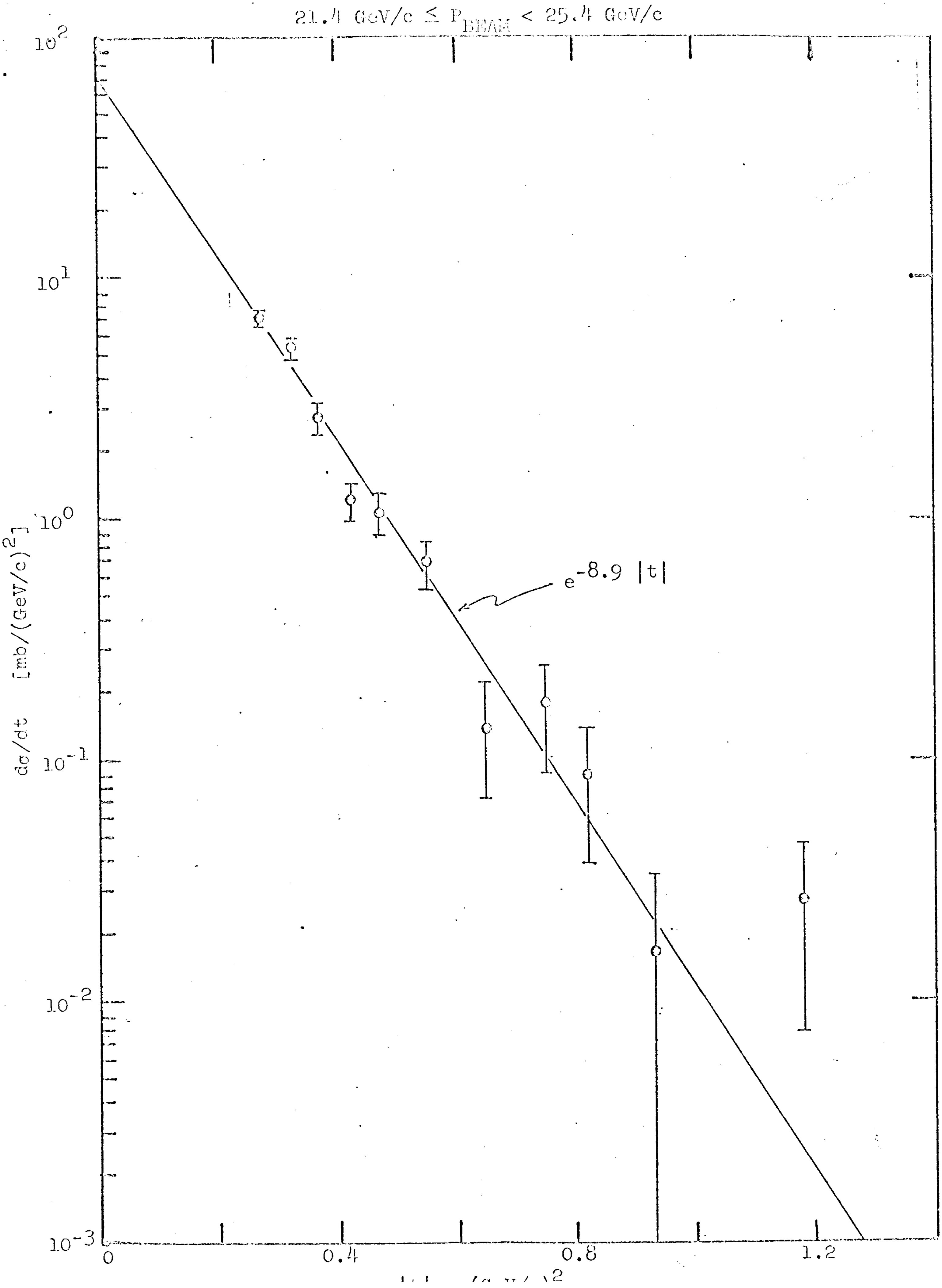


9.4 GeV/c ≤ P_BEAM < 13.4 GeV/c
10^2
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
dσ/dt [mb/(GeV/c)^2]
$e^{-7.7|t|}$
0
0.4
0.8
1.2

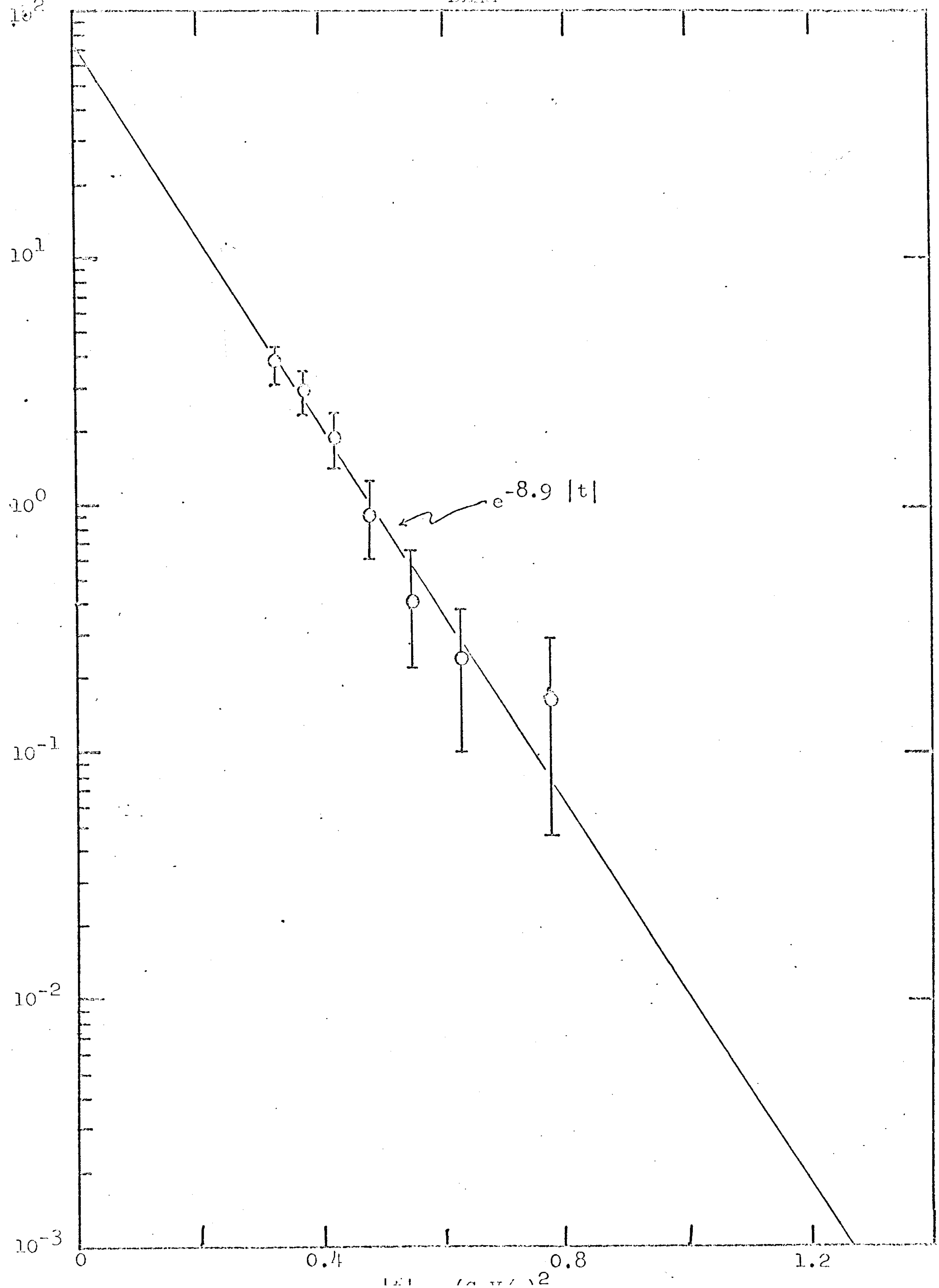


13.4 GeV/c ≤ P_BEAM < 17.4 GeV/c
dσ/dt [mb/(GeV/c)²]
|t| (GeV/c)²
e^-8.1 |t|
10²
10¹
10⁰
10⁻¹
10⁻²
10⁻³
0
0.4
0.8
1.2

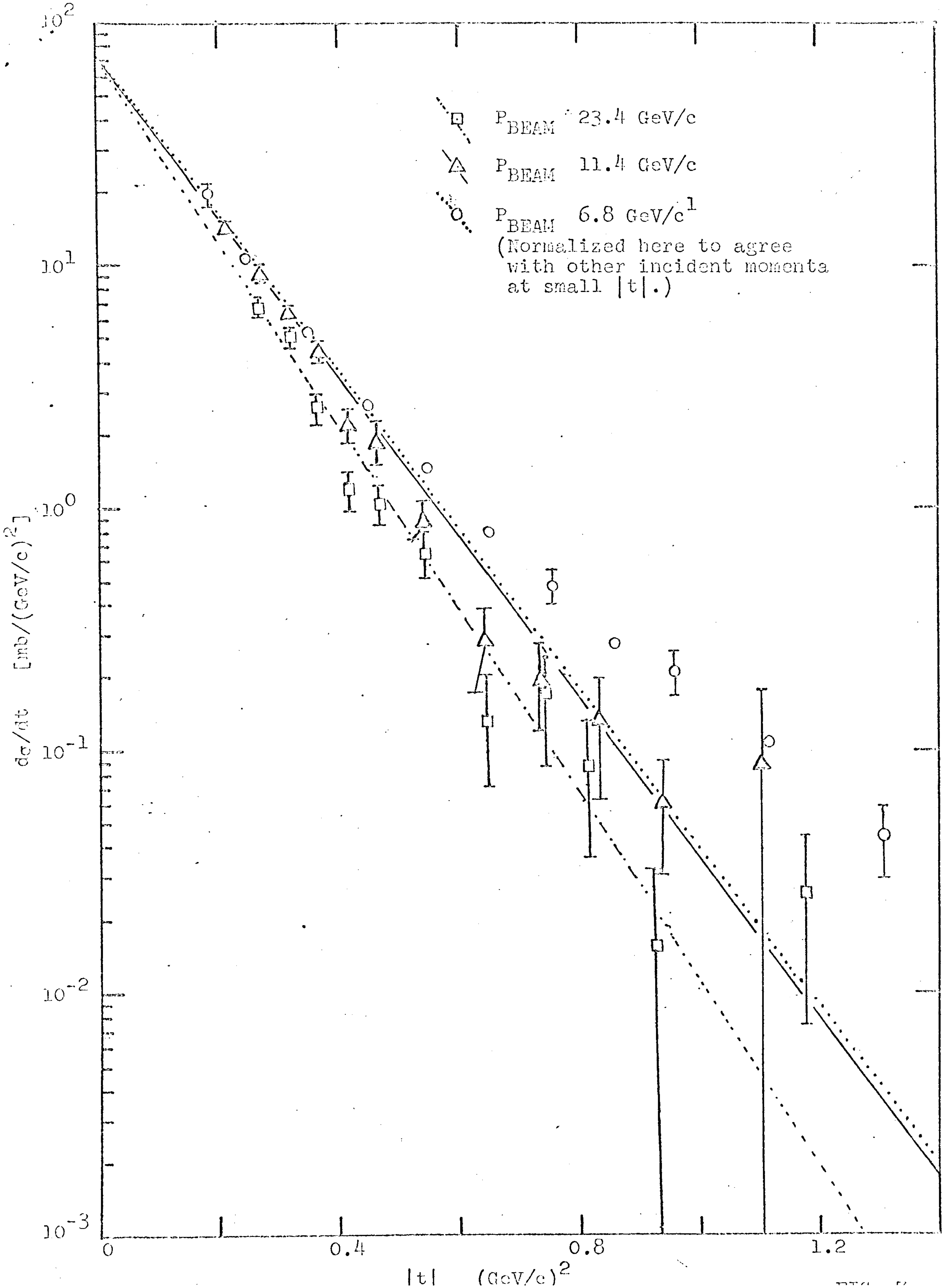

10^2
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
dσ/dt [mb/(GeV/c)^2]
$e^{-9.0\,|t|}$
0
0.4
0.8
1.2
|t| (GeV/c)^2



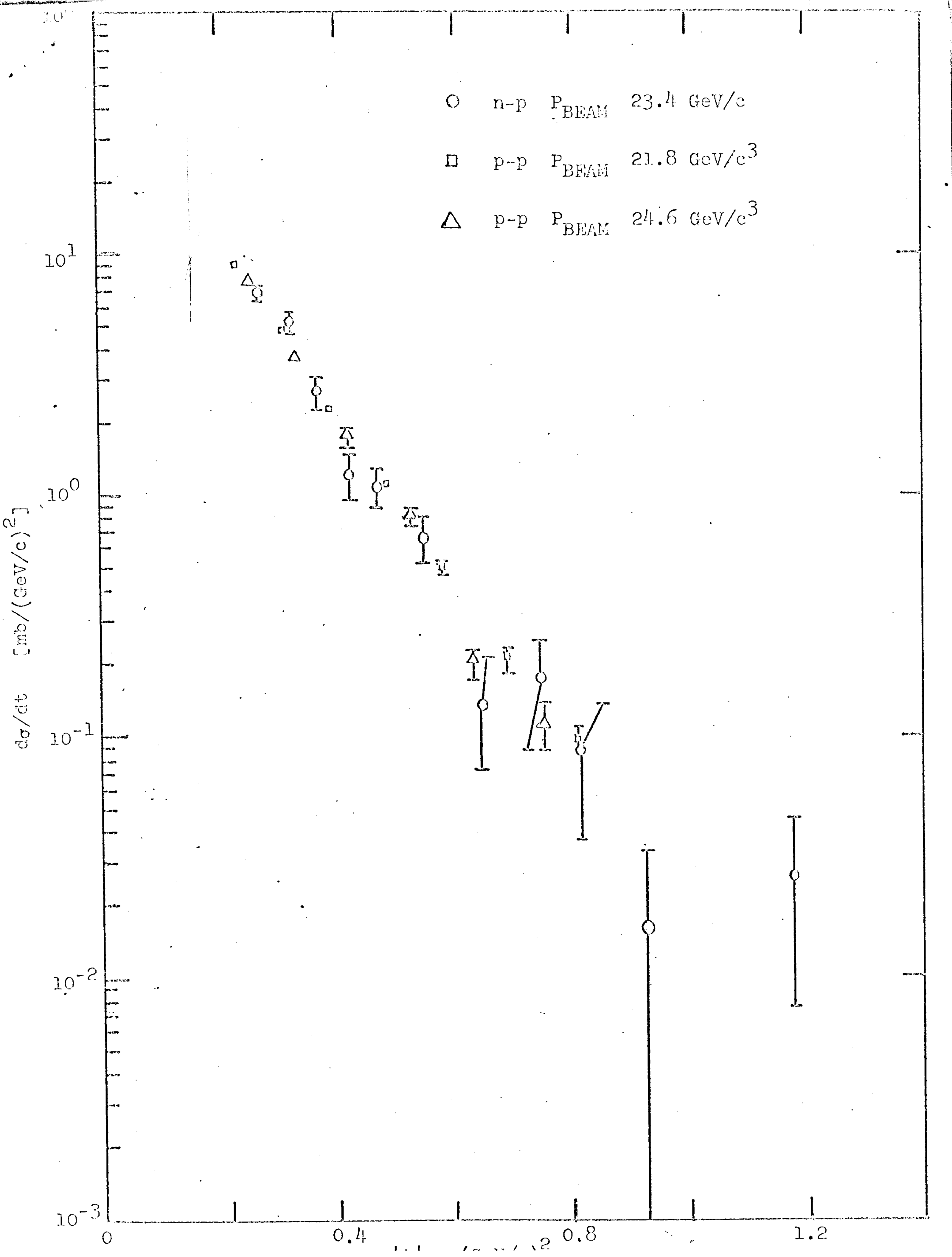
21.4 GeV/c ≤ P BEAM < 25.4 GeV/c
10^2
10^1
10^0
10^-1
10^-2
10^-3
dσ/dt [mb/(GeV/c)^2]
e^-8.9 |t|
0
0.4
0.8
1.2



25.4 GeV/c ≤ P_{BEAM} < 29.4 GeV/c
10^2
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
dσ/dt [mb/(GeV/c)^2]
$e^{-8.9 |t|}$
0
0.4
0.8
1.2



P_{BEAM} 23.4 GeV/c
P_{BEAM} 11.4 GeV/c
P_{BEAM} 6.8 GeV/c[1]
(Normalized here to agree with other incident momenta at small |t|.)
dσ/dt [mb/(GeV/c)^2]
10^2
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
0
0.4
0.8
1.2
|t| (GeV/c)^2



n-p P_{BEAM} 23.4 GeV/c
p-p P_{BEAM} 21.8 GeV/c^3
p-p P_{BEAM} 24.6 GeV/c^3
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
$d\sigma/dt$ $[mb/(GeV/c)^2]$
0
0.4
0.8
1.2